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क्रमदार मोटर — विशिष्टि

Indian Standard

STEPPING MOTORS — SPECIFICATION

UDC 621'313'2

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Rotating Machinery Sectional Committee, ETD 15

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FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Rotating Machinery Sectional Committee had been approved by the Electrotechnical Division Council.

This standard has been prepared to standardize the terminology used in connection with stepping motors, for detailing the important performance parameters for which the manufacturers should indicate values and for the establishment of recognized test methods for checking these values.

Annexes A, B, C and D are included giving respectively, typical presentation, typical basic performance curves and additional test methods for parameters for which the indication of values is not a requirement of this standard.

Annex E includes the most common dimensions in metric units for mounting. The dimensions in inch (FPS), if required, may be agreed between the manufacturer and the user. The mounting dimensions are recommendatory and have been added to guide the future designers.

This standard is adopted from BS 5000 : Part 60 : 1982 'Rotating Electrical Machines of Particular Types or for Particular Applications — Part 60 Stepping Motors', issued by the British Standards Institution (UK).

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

STEPPING MOTORS — SPECIFICATION

1 SCOPE

1.1 This standard covers the specific requirements for electromagnetic stepping motors. It defines the terminology used for this type of motor, lists of the items for which values are to be indicated *by* the manufacturer and specifies the test methods to be adopted. Dimensions are specified for given frame sizes; however, this standard is also applicable to motors in frames having any other dimensions.

1.2 Hydraulic and 'ratchet' type stepping motors are not included in this standard.

2 REFERENCES

2.1 The following Indian Standards are necessary adjuncts to this standard:

IS *No.*	*Title*
2223: 1983	Dimensions of flange mounted ac induction motors (*first revision*)
4029 : 1967	Guide for testing three-phase induction motors

3 DEFINITIONS

3.0 For the purpose of this standard, the following definitions shall apply.

3.1 Stepping Motor

A reversible brushless dc motor, the rotor of which rotates in discrete angular increments when its stator windings are energized in a programmed manner. Rotation occurs because of the magnetic interaction between the rotor poles and the poles of the sequentially energized stator phases. The rotor has no electrical winding but rather salient or magnetized poles.

NOTE — Particular types of stepping motor are defined in 3.1.1, 3.1.2 and 3.1.3.

3.1.1 *Permanent Magnet (PM) Stepping Motor*

A stepping motor utilizing a rotor that has permanently magnetized poles.

3.1.2 *Variable Reluctance (VR) Stepping Motor*

A stepping motor utilizing a rotor that has salient poles of low residual magnetic material.

3.1.3 *Hybrid (HY) Stepping Motor*

A stepping motor utilizing a permanent magnet to polarize salient pole pieces of low residual magnetic material on the rotor.

3.2 Damper

A device for damping step oscillations.

3.3 Dead Range or Dead Band

The angle between the clockwise and counter-clockwise limits under specified load conditions, within which the rotor of an energized stepping motor can stop.

3.4 Detent Position

That portion where the rotor of a permanent magnet or hybrid stepping motor comes to rest when unenergized and unloaded.

3.5 Detent Torque

The maximum steady torque that can be applied to the shaft of an unenergized stepping motor without causing continuous rotation.

3.6 Direction of Rotation

The direction of rotation of the shaft is the one observed when facing the shaft end associated with the mounting surfaces. Counter-clockwise rotation of the shaft is regarded as positive and clockwise rotation as negative.

3.7 Drive Circuit

A combination of the translator logic and a power amplifier that switches the phases of the stepping motor in a pre-determined mode.

NOTE — The available drive circuit configurations are defined in 3.7.1 to 3.7.5.

3.7.1 *Bipolar Drive*

A drive circuit in which the excitation applied is such that the torque generating current reverses in the windings.

3.7.2 *Chopper Drive*

A drive circuit in which the form of excitation is an initial high voltage applied to the phase winding until the current in that winding reaches a predetermined value when the supply is switched off. When the current has decayed to a second predetermined value, the voltage is re-applied.

3.7.3 *Constant Current Drive*

A drive circuit that attempts to maintain a constant current in the windings irrespective of motor speed.

3.7.4 *Multi-level Drive*

A drive circuit in which two or more levels of voltage are sequentially applied to a stepping motor winding.

3.7.5 *Unipolar Drive*

A drive circuit in which the excitation is such that the torque generating, current in each winding occurs in one direction only.

3.8 Holding Torque

The maximum steady torque at a specified current that can be applied to the shaft of an energized stepping motor without causing continuous rotation.

3.9 Incremental Motion

The motion caused by a single pulse or a programme of steps.

3.10 Line

A terminal or wire of the motor to which a logic function from the motor driver is applied. In the case of an electronic drive circuit, a power device will be connected to a line.

3.11 Load Angle

The angle between the magnetic axis of the rotor and the stator magnetic field. In practice, this, is the angle between the loaded and unloaded positions of the rotor under otherwise identical conditions.

3.12 Maximum Reversing Rate

The maximum, pulse rate at which the unloaded stepping motor is able to reverse and remain in synchronism under specified drive conditions.

3.13 Maximum Safe Working Temperature

The maximum temperature of the stepping motor, either continuously or intermittently rated, may safely be allowed to achieve (measured by the change of winding resistance method). This may bear little or no relation to the class of insulation used in the construction of the motor but may be dictated by considerations such as bearing lubricant, etc.

3.14 Maximum Slew Rate

The maximum pulse rate at which the unloaded stepping motor can remain in synchronism under specified drive conditions.

3.15 Mini-Stepping

The sub-division of motor's basic stop angle by partial energization of a phase or phases.

3.16 Nose or Step Sequence

A particular sequence of excitation defined by the drive circuit which, when applied to a stepping motor, will energize certain windings or phases.

3.17 Overshoot or Transient Overshoot

The amount the shaft of the stepping motor rotates beyond the final commanded step position.

3.18 Phase

A part of the winding between a line and the centre tap or star point, or the winding between two lines if no centre tap or star point exists.

3.19 Positional Error

The deviation from the theoretical final position after a sequence of steps, expressed as a percentage of basic step angle.

3.20 Pull-in Rate

The (constant) maximum pulse rate at which the energized stepping motor will start driving a specified load without missing steps, under specified drive conditions.

3.21 Pull-in Torque

The maximum torque at which an energized stepping motor will start driving a specified load and run in synchronism without losing steps, on, application of a fixed pulse rate.

3.22 Pull-Out Rate

The (constant) maximum pulse rate at which the energized stepping motor can run, driving a specified load without missing steps, under specified drive conditions.

3.23 Pull-Out Torque

The maximum torque that can be applied to the rotating shaft of a stepping motor driven at a given pulse rate under specified drive conditions, without missing steps.

3.24 Residual Torque

In case of permanent magnet stepping motor, it is the non-energized detent torque due to the effects of the permanent magnet and bearing friction.

3.25 Pulse Rate

The rate at which the (successive) steps are initiated.

3.26 Resolution

The reciprocal of the number of steps per revolution of the motor shaft.

3.27 Resonant Rate

A stepping rate at which the stepping motor will miss steps when operating below the pull-out torque curve, under specified load and drive conditions.

3.28 Response Range

The range of pulse rates over which the motor can start, stop or reverse without missing steps under specified load and drive conditions.

3.29 Salient Pole

A projecting pole on a rotor or stator.

3.30 Settling Time

The total time from the application of the command signal until the motor shaft comes to rest.

3.31 Slew Range

The range of pulse rates over which the motor will not miss steps unidirectionally under specified load and drive conditions, but within which the motor cannot start, stop or reverse at a fixed pulse rate.

NOTE - This is illustrated in Fig. 6.

3.32 Step

The movement of the rotor from one energized position to the next in sequence.

3.33 Step Angle (Basic)

The angle through which the shaft of an unloaded stepping motor can be made to turn when two adjacent phases are energized, singly in sequence.

3.34 Step Angle Error

The maximum percentage deviation from the theoretical step angle.

3.35 Step Position

The angular position that the shaft of an unloaded stepping motor assumes when it is energized without causing continuous rotation. The step position is not necessarily the same as the detent position.

3.36 Stepping Rate

The number of step angle through which the stepping motor shaft rotates in a specified time.

3.37 Synchronism

The state that exists when the stepping rate of the rotor equals the applied pulse rate.

3.38 Torque Gradient

The average slope of the torque displacement curve over a specified angle through the origin.

3.39 Translator Logic

The logic that translates the input pulse train into the selected made pattern to be applied to a stepping motor.

4 ABBREVIATIONS, SYMBOLS AND UNITS

4.1 The abbreviations, symbols and units commonly used are listed in Table 1.

5 TYPICAL MODES

5.1 There are three preferred sequences as excitation, mode A, mode B and mode AB. Typical modes for a three-phase motor are detailed in Annex A.

Table 1 List of Abbreviations, Symbols and Units

(*Clause* 4.1)

Term	Abbreviation or Symbol	Unit	Unit Symbol
Dead range	—	Degree	°
Detent torque	Td	Newton metre	N.m
Holding torque	Th	Newton metre	N.m
Maximum slew range	—	Steps per second	—
Mode	A, B or AB	—	
Overshoot (transient)	—	Degree	°
Phase	ϕ	—	—
Positional error	—	Percent basic step angle	%
Pull-in rate	Fpi	Steps per second	—
Pull-out rate	Fpo	Steps per second	—
Pull-in torque	Tpi	Newton metre	N.m
Pull-out torque	Tpo	Newton metre	N.m
Pulse rate	pps	Pulses per second	Hz
Resolution		Steps per revolution	—
Resonant rate	—	Steps per second	—
Response range	—	Steps per second	
Settling time	—	Second	—
Slew range	—	Steps per second	—
Step angle	—	Degree	°
Step angle error	—	Percent basic step angle	%
Stepping rate	—	Steps per second	—
Torque gradient	—	Newton metre per degree	N.m/°

6 VALUES TO BE INDICATED BY THE MANUFACTURER

6.1 The manufacturer shall indicate values for parameters listed below. These shall be confirmed, where appropriate, by the tests specified in 9. Where the parameters are affected by the drive circuit or load, details of that drive circuit or load shall be included in the declaration. The parameters are:

a) Detent torque,

b) Step angle (basic),

c) Step angle error,

d) Steps per revolution,

e) dc volts or amperes per phase,

f) Inductance per phase,

g) dc resistance per phase,

h) Holding torque,

j) Volts (peak to peak) per thousand revolutions per minute as generator (where applicable),

k) Rotor inertia,

m) Insulation class, and

n) Maximum safe working temperature.

6.2 The manufacturer may give additional information in the literature accompanying the motor, the details of which are given in Annex B. The basic performance curves are given in Annex C.

7 LEAD IDENTIFICATION AND TERMINAL NUMBERING

7.1 For motors with loose leads the colours of the leads (or marker sleeves fitted to the leads) shall be as given in Table 2. Colours in parentheses are non-preferred alternatives. Motors with terminal boards or strips shall have the terminals identified by numbers as given in Table 2.

7.2 Where bipolar drives are used in conjunction with eight-lead motors, it is necessary to connect the windings so that the torques associated with each winding are added, not subtracted; in compliance with Table 2, the winding connections will then be as shown in Fig. 1.

Table 2 Lead Identification and Terminal Numbering’

(*Clauses* 7.1, *and* 7.2)

a) No Star Point or Common Connection

Phase	Phase Start Colour	Phase Finish Colour
1	Brown	Brown/White
2	Red	Red/White
3	Orange	Orange/White
4	Yellow	Yellow/White
5	Green	Green/White
6	Blue	Blue/White
7	Lilac	Lilac/White
8	Grey	Grey/White

b) With Star Point or Common Connection

Phase	Colour	Terminal Number
Three-phase with Star Point		
1	Brown	1
2	Red	2
3	Orange	3
Star-point	Black (white)	4
Four-phase with Star Point		
1	Brown	1
2	Red	2
3	Orange	3
4	Yellow	4
Star-point	Black (White)	5
Four-phase with Common Connections		
1	Brown	1
2	Orange	3
3	Red	2
4	Yellow	4
Common connections	Brown/Orange (Black)	5
	Red/Yellow (White)	6

8 DIMENSIONS

8.1 The most common dimensions (in mm) for mounting the motor are given in Annex E. At present, the designs of stepping motors within the scope are mainly based on ‘inch’ dimensions. This standard specifies the approximate ‘millimetre’ conversions of the ‘inch’ dimensions but these conversions are not exact. If the user desires the dimensions in ‘inch’ units, the same should be agreed at the enquiry stage. For frames sizes given in col 1 of Tables 3 and 4, the dimensions shall be as given in those tables. For designs having dimensions other than those given in Tables 3 and 4 the dimensions are not standardized.

9 TESTS

9.1 General

9.1.1 *Confirmation of Values*

The manufacturer shall carry out the tests given in this clause to confirm the values which have been indicated in accordance with 6 and also a high voltage test in accordance with 9.5.

The additional parameters and their test methods are given in Annex D. However, these do not form part of parameters to be checked for compliance with this standard. These are given

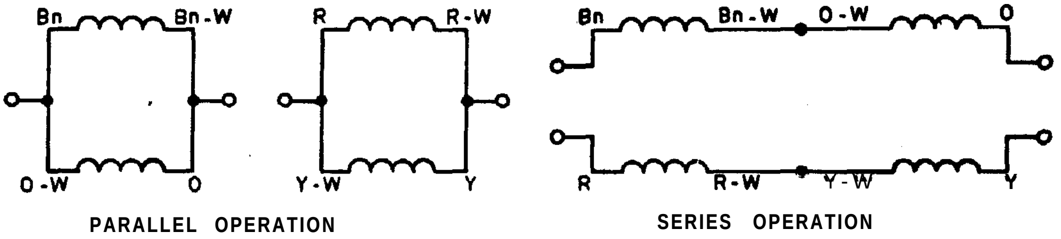


FIG. 1 WINDING CONNECTIONS FOR BIPOLAR DRIVES

Table 3 Approximate Installation Dimensions for Standard Frame Sizes (mm)

(*Clauses* 8.1, E-l and E-3)

Frame Size	Fig.	*C*	*D*	*E*	*H*	*I*	*J*	*K*	*L*	*C′*	*O*	*P*
05	12	12’70 12·62	— —	9·525 9·512	1·09 0·94	— —	1·09 0·94	1·09 0·94	11.18 11·02	—	— —	— —
08	12	19.13 18·92	— —	12·700 12·687	1·14 0·89	— —	1·70 1·45	1·70 1·45	17’58 17.32		— —	— —
11	13	27.05 26.85	25400 25·387	15·875 15.863	1·70 1·45	1·70 1·45	2·49 2·24	1·14 *Min*	24·80 24·64	— —	20·70 20·55	— —
15	13	36.58 36·37	33.325 33.312	22·225 22.212	1·14 1·89	3·48 3.23	2.49 2.24	2·11 1.85	33·45 33·20	— —	28·02 27·86	— —
18	13	44·53 44.32	39.675 39.662	23·813 23·800	1·15 0·89	3.48 3.23	2·49 2.24	2·11 1·85	41·35 41’20	31·83 31·67	—	— —
20	12	51·05 50.55	— —	44·50 44.40	6’73 5.97	— —	3.30 3·05	2·49 2.24		47.75 47·50	— —	— —
23	13	57.15 57.02	50·80 50·77	23·813 3·792	1·70 1·45	5.21 4.95	3·30 3·05	2.67 2.41	52’53 *Max*	57.23 *Max*		— —
23	14	57‘99 *Man*	— —	38·15 38’05	1.96 1·19	— —	5.03 4·52	—	— —	57.99 *Max*	47.27 47.02	5.46 4’95
34	14	86 *Max*	— —	73.08 72’97	3’30 *Max*	— —	5·33 4.32	—	— —	86 *Max*	69.72 69.47	5.92 5·41
42	12	109 *Max*	— —	55·58 55·47	1·70 1·45	— —	— —	— —	— —	—	76.33 76·07	— —
42	14	109 *Max*	— —	55·58 55·47	1·70 1·45	— —	— —	— —	— —	109 *Max*	89.03 88·77	6·86 *Min*

for the purpose of standardization of test procedure when agreed between the manufacturer and the purchaser.

NOTE - These tests are not normally to be repeated except by special agreement between the manufacturer and the purchaser.

9.1.2 *Type Tests*

Where tests are indicated as type tests, these shall be made on motors as produced by a specific manufacturer before that manufacturer supplies, on a general basis, motors designed to comply with the requirements of this standard,

9.1.3 *Routine Tests*

Where tests are indicated as routine tests, these shall be made on all motors in the finished state or, as appropriate, during manufacture.

NOTE — These tests may also be used as acceptance tests by agreement between the manufacturer and the purchaser.

Table 4 Approximate Shaft Dimensions for Standard Frame Sizes (mm)

(*Clauses* 8. I, E-l and E-4)

Frame Size	Figure	*A*	*F*	Number of Teeth	Diametral Pitch
05	12	9·78 9·27	3·167 3·155	10	96
08	12	9·78 9·27	3·167 3·142	13	120
08	12	9.78 9.27	3·167 3·142	—	—
11	13	9·78 9.27	3’167 3·142	13	120
11	13	9·78 9·27	3·167 3·155	—	—
15	13	11·48 10·72	4·496 4·470	15	96
15	13	11·48 10·72	4·763 4·737	—	—
18	13	14·66 13·89	4·496 4·470	15	96
20	12	16·64 15·11	6·350 6·337	—	—
23	13	14·73 13·97	6·342 6·317	22	96
23	14	21·34 19·81	6·350 6·325	—	—
34	14	30·925 29·401	9·525 9·512	—	—
42	12	35·69 34.16	12·700 12’687	—	—
42	14	35.81 34.29	15.875 15.862	—	—

9.1.4 *Stabilized Test Conditions*

Before carrying out tests, the motor shall be temperature stabilized in accordance with the manufacturer’s instructions.

9.1.5 *Magnet Stabilization*

For motors containing a permanent magnet, before performance tests are carried out, the magnet shall be stabilized in accordance with the manufacturer’s instructions.

9.2 Rotor Inertia (Type Test)

9.2.1 *Calculation Method*

Where a rotor is cylindrical, calculate the moment of inertia about its axis from the formula:

$$I = \frac{mr^2}{2}$$

where

I is the moment of inertia (in g.cm^2),
m is the mass (in g), and
r is the radius (in cm).

9.2.2 *Single Wire Hanging Method*

Where the rotor has salient poles, direct calculation is more complex. It is permissible to use the following formulae in conjunction with a ‘hanging wire’ on which the rotor is hung. Compare the period of oscillation (rotating about the axis of the shaft) to that of a known slug. The moment of inertia is then given by the formula:

$$I_u = I_k \left(\frac{T_u}{T_k} \right)^2$$

where

I_u = moment of inertia of rotor (in g.cm^2),
I_k = moment of inertia of known slug (in g.cm^2),
T_u = period of rotor (in s), and
T_k = period of known slug (in s).

If the difference in mass between the reference slug and the rotor is so wide that different wires have to used to be obtain straightness and reasonable periods of oscillation, then use an intermediate slug. Measure the period of oscillation of this intermediate slug on each wire and calculate the moment of inertia of the test rotor from the following formula:

$$I_u = I_k \left(\frac{I_u}{I_k} \right)^2 \times \left(\frac{T_{w1}}{T_{w2}} \right)^2$$

where

T_{w1} = period of intermediate slug on wire used for 6, and
T_{w2} = period of intermediate slug on wire used for I_u.

The moment of inertia of the intermediate slug is not required.

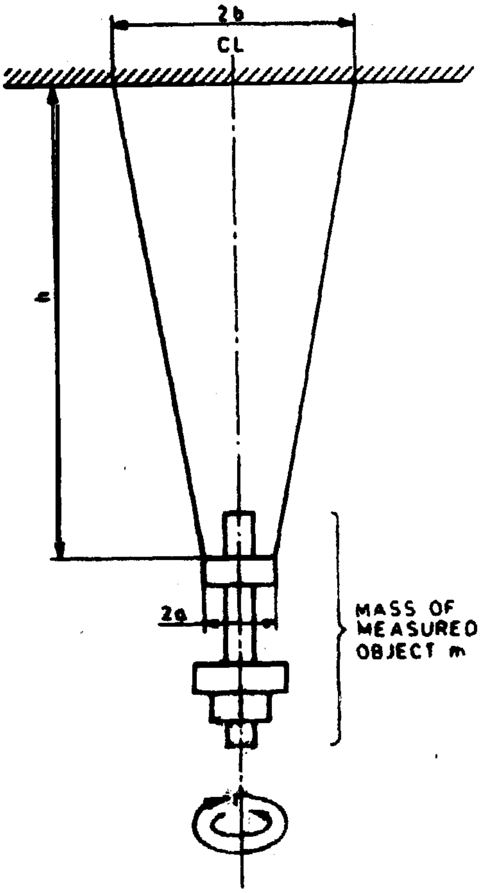
9.2.3 *Two Wire **Hanging** Method*

Hang the rotor by two slender steel wires, as illustrated in **Fig.** 2, and apply torsional vibration with the centre line *CL* as the axis. Measure the period *T* of torsional vibration and calculate the moment of inertia from the following formula:

$$I = \left(\frac{T}{2\pi} \right)^2 \cdot \frac{abmg_n}{h}$$

where

I = moment of inertia (in g.cm^2),
T = time of one cycle oftorsional vibration (in s),
a = one-half the distance between the steel wires on the measured object (in cm),
b = one-half the distance between the steel wires at fixed point (in cm),



Fra. 2 TWO WIRE HANGING METHOD TO DETERMINE ROTOR INERTIA

h = hanging distance of measured object (in cm),,
m = mass of measured object (in g), and
g_n = standard gravitational acceleration = 981 cm/s^2.

The test wire or wires shall be at least 3 m long and screened from draught. Take care that each wire is firmly attached at its upper end and any adaptors or fastenings at its lower end are secure. Do not allow any movement at the anchorage points. The wire shall be substantially straight and free from kinks, It is important that both rotor and slug are seen to rotate concentrically. When checking magnetic rotors, take care to ensure that no magnetic materials (for example, radiators on cabinets) are near.

9.3 Inductance (Type Test)

The inductance of a stepping motor winding varies both with rotor position and with excitation current. Measurements can also be affected by the rate of change of current, thus when a figure for inductance is given, the conditions under which the measurements were taken shall be quoted.

9.3.1 *Inductance Bridge Method*

Use a bridge having a test frequency of 1 000 Hz or less. Align the stepping motor rotor and stator by the application of the rated current to the winding under test and then clamp the shaft relative to the motor body, de-energize the stator and measure the inductance (using a test voltage of approximately 1 Vrms). Then turn the rotor through an angle equal to half its tooth or pole pitch (the point of minimum reluctance) and repeat the measurement. These measurements are the incremental unenergized aligned and unaligned inductances are the minimum requirements to be indicated in accordance with 6. Additional useful information can be obtained by injecting current into the windings when measuring the inductance. Three levels of bias current are desirable, namely, 0 percent, 50 percent and 100 percent of the motor's rating. This then requires six measurements, three with the rotor and stator in the aligned position and three with the rotor and stator in the aligned position and three with the rotor and stator out of line. When a bias current is applied to a winding, the inductance measuring device will be affected by the impedance of the biasing supply, and it is for this reason that a high impedance source is required. A typical circuit is shown in Fig. 3.

9.3.2 *Current Discharge Method*

Align the stepping motor rotor and stator and clamp the rotor as described in 9.3.1. Energize the winding for sufficient time to stabilize the current to a figure 10 percent above the motor rating. Close a switch, short-circuiting the winding and monitor the resulting current decay on an oscilloscope connected across a resistor placed in series with the winding (see Fig. 4). Record the resulting curve. Repeat this procedure with the rotor in the unaligned position. Calculate the inductance of the winding for any part of the curve (any current area) from the following formula:

$$L = \frac{RT}{l_n \frac{I}{i}}$$

where

L = inductance (in H),
I = initial current (in A),
i = current after time T (in A),
R = total circuit resistance including winding (in ohms),
T = time between Z and i (in s), and
l_n = natural (Napierian) logarithm.

Alternatively, if T is in ms then L is in mH.

9.3.2.1 Give the two curves (aligned and non-aligned together with the above formula or give a table of inductances at different currents.

9.3.2.2 Any values given shall be accompanied by the relevant circuit constants.

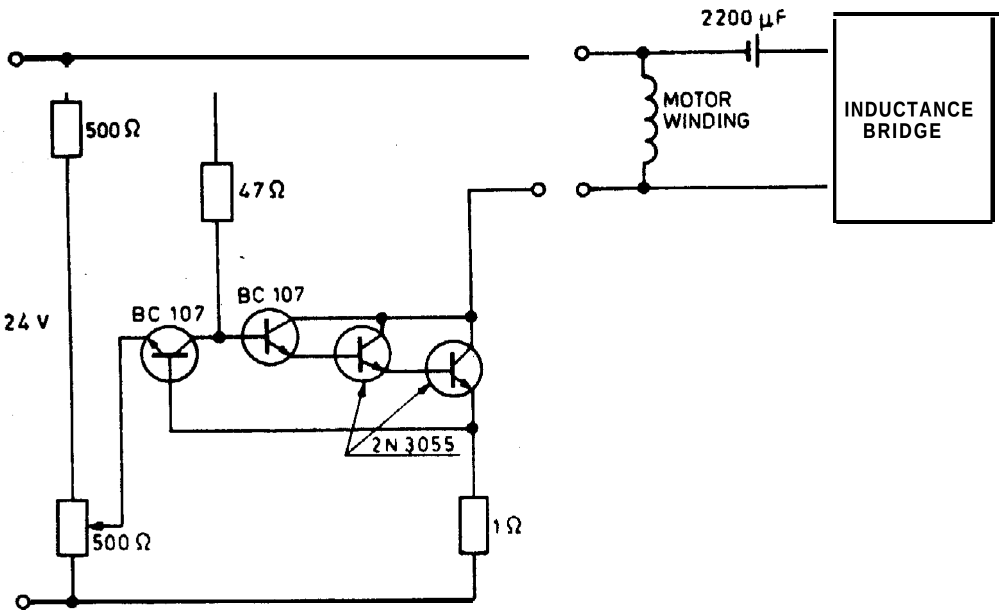


FIG. 3 TYPICAL CIRCUIT FOR MEASURING INDUCTANCE BY AN INDUCTANCE BRIDGE

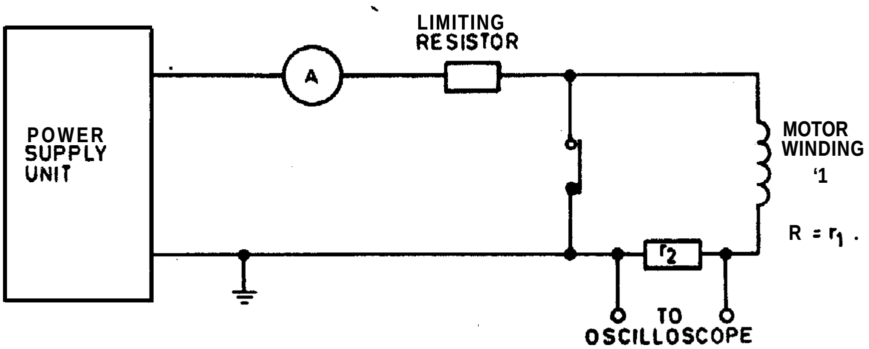


FIG. 4 CIRCUIT FOR MEASURING INDUCTANCE BY THE CURRENT DISCHARGE METHOD

9.4 dc Resistance (Routine Test)

Measure the dc resistance of each winding with the stepping motor at room temperature. If this is other than 20°C, correct the resistance accordingly.

9.5 High Voltage Test (Routine Test)

Carry out the high voltage test in accordance with the method given in IS 4029 : 1967, but with the test voltage given in Table 5.

Table 5 Test Voltage for High Voltage Test

Frame Size	Test Voltage (rms)
up to11	250 V
Above 11 and up to 42	500 v
Above 42 and up to 100	500 V plus twice the rated voltage
Above 100	1 000 V plus twice the rated voltage

9.6 The Motor as a Generator (Type Test)

This test applies to permanent magnet and hybrid motors only.

9.6.1 Drive the shaft at 1 000 r/min ± 5 percent and measure the peak to peak voltage appearing across one of the phases with a device whose impedance is sufficiently high that the measured voltage is substantially unaffected. Take care that all other winding teminations are isolated so that the open circuit conditions are monitored. The measured value of volts per 1 000 r/min is the figure to be indicated.

NOTE — For reference purposes, it is advisable to record the output voltage curve driving the shaft from 0 to 3 000 r. min.

9.7 Step Angle Error (Type Test)

9.7.1 *General*

Measure the step angle error by any convenient means available, provided that the measuring device has the desired accuracy and is of sufficiently low friction that the accuracy is unaffected. The methods given in 9.7.2, 9.7.3 and 9.7.4 are provided as a guide, but are not obligatory.

9.7.2 *Encoder Method*

An optical encoder can provide a very satisfactory research and production tool for stepping motor step angle error measurements that are quick and unambiguous. However, it is necessary to take some care in the selection of a suitable encoder. For a large angle stepping motor an absolute device is suitable, but for small angle (1'8") stepping motors it will be found that an incremental encoder will provide greater resolution. When using an incremental encoder consider the following points. The count speed of an incremental encoder is limited, and so the angular velocity the motor shaft achieves between steps is limited. Add viscous damping or add inertia to the shaft, but take care that the inertia is sufficiently well balanced that the motor accuracy is not impaired. An encoder is generally accurate only to a half count and the read-out facility to ± 1 digit; this then for a given encoder resolution will limit the accuracy.

9.7.3 Synchro *Method*

An accuracy similar to that of the incremental encoder can be obtained with a synchro without the risk of losing track of position since the synchro is basically an absolute device. It requires, however, special supplies and read-out facilities.

9.7.4 *Dividing Head Method*

This method is not considered suitable for production checks, but gives a more accurate result for development purposes. Carefully secure the motor body in the chuck of a dividing head, aligning up the motor shaft axis with the dividing head axis. With the required phase or phases energized, focus the optics on to a scribed line on the shaft or on a drum on the shaft. With the next phase or phases energized, turn the chuck until the. scribed mark a gain appears within the graticule and note the angular reading.

If it is desired to determine the maximum positional error, use the midpoint between the two extremes of positional error as the zero postion.

9.8 Detent Torque (Type Test)

Energize the stepping motor momentarily to determine the step position for a particular step. Remove the energizing source and determine the detent torque in a similar way to that of the holding torque (see 9.9).

9.9 Holding Torque (Routine Test)

Measure the holding torque with the stepping motor at room temperature unless measurement at operating temperature has been specified. For current operated motors apply the rated current to the winding or windings required and keep this constant throughout the test. For voltage operated motors apply the rated voltage to the winding or windings required, note the current and keep this constant throughout the test. Apply a load to the motor shaft by any convenient means (for example, weights added to a scale pan suspended from a pullev or balance arm). Increase the load until continuous rotation just commences. The maximum load achieved before continuous rotation is the holding torque. Take all readings as quickly as possible, even with a constant current supply. the torque may fall due to increasing tomperature.

NOTES

1 It should be noted that the angle through which the shaft rotates for no load to peak load varies according to the design of the machine. and allowance should be made for the torque loading device to make a sufficient rotation without impairing the accuracy of the reading.

2 It is often of value to quote the peak holding torque at various supply levels. The measuring technique is the same as above, but measurements are taken at 25 percent, 50 percent, 75 percent and 100 percent of rated supply and the results normally presented as a curve.

10 RATING PLATE

10.1 The motor rating plate shall contain the following information:

a) Reference to this standard IS 13079 : 1991;

b) Indication of the source of manufacturer;

c) Type indication, if appropriate (for example, PM, VR or HY);

d) Manufacturer's serial number and/or date code;

e) Nominal voltage or peak current; and

f) Number of phases.

10.1.1 If it is possible to include additional information, it is recommended that the following should be given, otherwise the literature (see Annex B) giving the information should be enclosed:

a) Resistance per phase,

b) Modification state,

c) Number of steps per revolution or step angle (basic),

d) Winding configuration, and

e) Diagram of lead colours.

The Stepping Motors may also bc marked with the Standard Mark.

ANNEX A

(*Foreword* and *Clause* 5.1)

TYPICAL MODES FOR A THREE-PHASE STEPPING MOTOR

A-1 Table 6 shows the three preferred sequences of excitation, mode A, mode B and mode AB, for a three-phase motor. Where a three-phase rotor is being driven, the sequence designation can be prefixed by the digit 3 and, if four-phase, by the digit 4 (that is, a three-phase motor driven in mode B would have the drive circuit designated mode **3B,** and for a four-phase motor mode 4B).

Table 6 Typical Modes for a Three-Phase Stepping Motor

MODE A

Step	Phase 1	Phase 2	Phase 3
1	1	0	0
2	0	1	0
3	0	0	1
1	1	0	0

MODE B

Step	Phase 1	Phase 2	Phase 3
1	1	1	0
2	0	1	1
3	1	0	1
1	1	1	0

MODE AB

Step	Phase 1	Phase 2	Phase 3
1	1	0	0
2	1	1	0
3	0	1	0
4	0	1	1
5	0	0	1
6	1	0	1
1	1	0	0

NOTE — Logic 1 represents phase energized. Logic 0 represents phase unenergized. Sequence can be extended for any number of phases.

ANNEX B

(*Foreword* and *Clauses* 6.2 *and* 10.1.1)

B-1 CATALOGUE PRESENTATION

B-1.1 It is recommended that for uniformity of presentation and ease of comparison, the following information should be given in manufacturers' catalogues, as far as reasonably possible:

a) The values to be indicated by the manufacturer in accordance with 6,

b) The appropriate information as illustrated in Fig. 5,

c) Maximum permissible axial thrust,

d) Maximum permissible overhung load (at a specified position), and

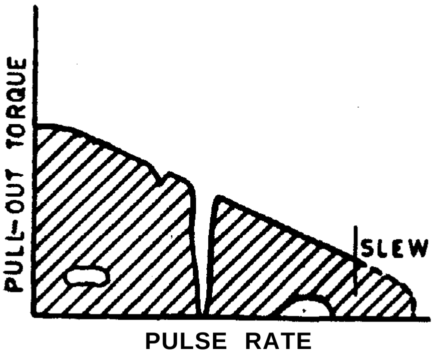
e) Mass of the motor.

ANNEX C

(*Foreword* and *Clause* 6.2)

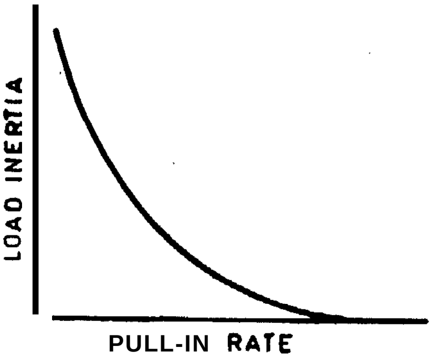
C-1 BASIC PERFORMANCE CURVES

C-1.1 The curves in Fig. 6 show the basic dynamic characteristics of a given stepping motor relate to each other. The drive circuit and any inertia load, for example, pulley, that might affect the performance should be quoted in order that the curves are of use. The major resonant areas but, since the curves are for guidance only, it is not anticipated that all resonant areas will be defined.



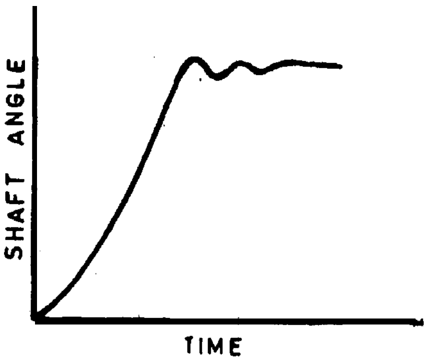
TO BE GIVEN:
INERTIA OF LOAD
TYPE OF DRIVE CIRCUIT

PERMITTED AREAS OF OPERATION (INDUCTANCE-RESISTANCE DRIVE)



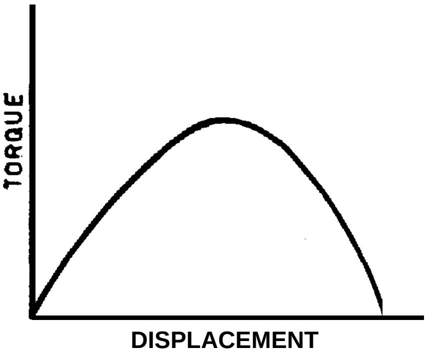
TO BE GIVEN:
DETAILS OF EXTERNAL LOAD (IF ANY)
e.g. FRICTION OF DRIVEN, DEVICE

PULL-IN RATE / LOAD. INERTIA



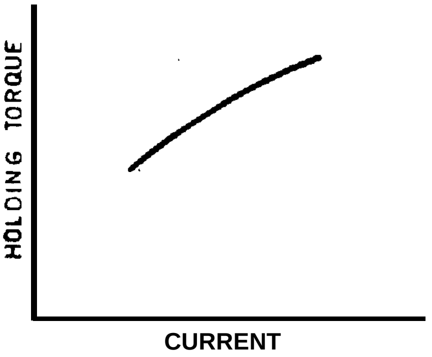
TO BE GIVEN:
INERTIA OF LOAD
TYPE OF DRIVE. CIRCUIT

ONE STEP RESPONSE



TO BE GIVEN:
TORQUE REQUIRED FOR DISPLACEMENT AGAINST DETENT TORQUE OR HOLDING TORQUE (PARTIALLY ENERGIZED)

TORQUE /DISPLACEMENT CURVE



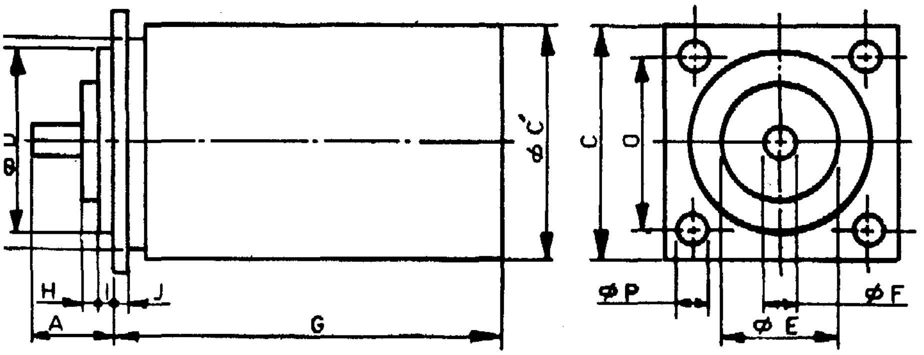
TO BE GIVEN:
HOLDING TORQUE AS A FUNCTION OF CURRENT

HOLDING TORQUE /CURRENT CURVE

PHASE	1	2	3	4
STEP 1	0	0	1	1
2	1	0	0	1
3	1	1	0	0
4	0	1	1	0
1	0	0	1	1

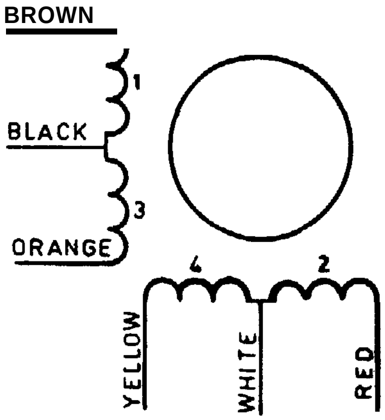
To BE GIVEN:
SEQUENCE FOR COUNTER-CLOCKWISE ROTATION

PHASE-OPERATING SEQUENCE



TO BE GIVEN:
FRAME SIZE (IF STANDARD AS TABLE 5) OR PRINCIPAL OUTLINE DIMENSIONS

OUTLINE DIMENSIONS



TO BE GIVEN:
WINDING CONNECTIONS
LEAD COLOURS

CONNECTION DIAGRAM

FIG. 5 ILLUSTRATIONS OF VALUES TO BE GIVEN BY THE MANUFACTURER WHERE APPROPRIATE

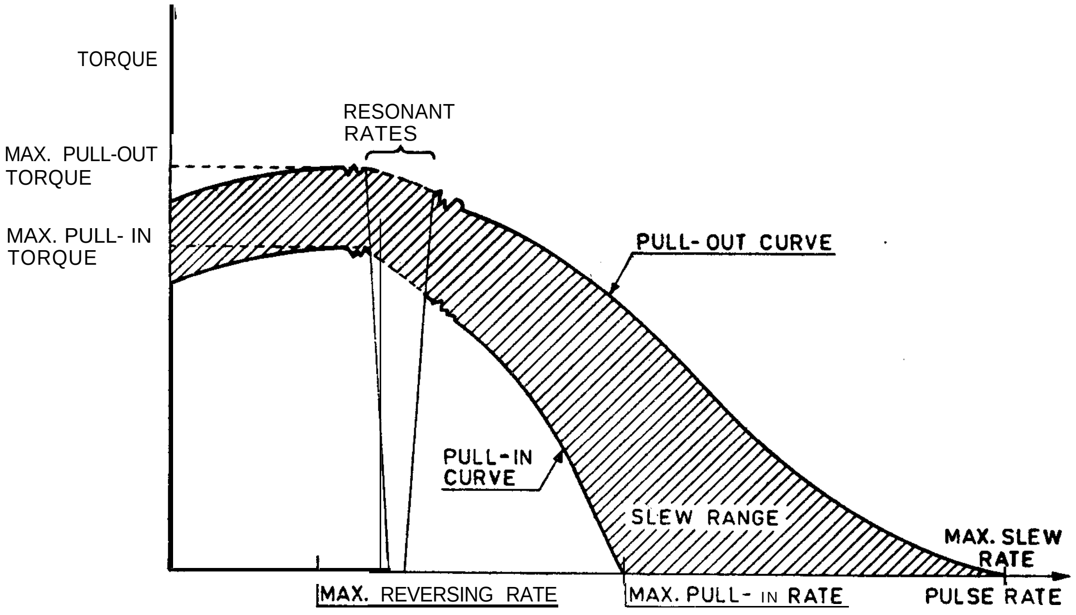


FIG. 6 BASIC PERFORMANCE CURVES

ANNEX D

(*Foreword* and *Clause* 9.1.1)

ADDITIONAL TEST METHODS

D-1 GENERAL

These additional test methods cover tests for parameters which are not specified as requirements of this standard. but for which it is nevertheless though desirable that methods of test should be standardized.

D-2 MEASUREMENT OF WINDING TEMPERATURE RISE

Where possible, the change of winding resistance should be used to measure the temperature rise of a stepping motor. Mount the motor, away from heat conducting surfaces and draughts, and attach to heat sink where appropriate. When the motor stabilizes at ambient temperature, record the motor temperature ± 1 and the winding resistance R_1.

Energize the relevant windings on the appropriate duty cycle until the motor attains a stable temperature.

For voltage driven motors energize one or more phases as required, but at zero pulse rate, that is, the phases specified are energized continuously, the others being open-circuited. Use one of the energized phases for the temperature rise measurements.

Current driven motors at a speed such that the maximum power input is achieved (shaft unloaded). This will generally be the maximum pull-in rate. A maximum temperature is then achieved. Where it is not possible to run the motor in this condition (at its maximum pull-in rate), choose a pulse rate and quote this along with the temperature rise and the drive circuit used.

When the temperature has stabilized, rapidly transfer the motor connections to a resistance bridge and take the new resistance reading, R_2, as quickly as possible.

The temperature-rise is 'then given by the formula:

$$t = \frac{(R_2 - R_1)(k + t_1)}{R_1}$$

and the final temperature by the formula:

$$t_2 = \frac{R_2}{R_1} (t_1 + k) - k$$

where

t = temperature-rise (in K);

t_1 = initial temperature (in °C);

t_2 = final temperature (in °C);

R_1 = resistance at t_1 (in Ω);

R_2 = resistance at t_2 (in Ω); and

k = the constant for winding conductor material and is the reciprocal of the temperature coefficient of the material at 0°C (for copper, k = 235 and for aluminium, k = 228).

D-3 TORQUE DISPLACEMENT CURVE

Apply the rated current or voltage as described in 9.9. Measure the torque by adding weights to a torque arm, but when the peak holding torque is attained use a spring balance to prevent the arm from rotating uncontrollably, when obtaining figures on the nagative portion of the curve. In order for measurements to be stable it is necessary for the spring balance stiffness to be greater than that due to the motor, which may mean that a high rate balance has to be used and that accuracy of reading will be poor. Monitor the shaft angle on large angle stepping motors with a protactor and pointer. For small angle motors it will be necessary to use more sophisticated test gear. Where the motor has shaft extensions at each end use an optical encoder to monitor the angle, and a torque transducer to monitor the torque applied. The load may then be applied by hand via a load arm and the readings obtained from the encoder and torque transducer are directly plotted on a chart using an X Y plotter. Where the motor has one shaft only, apply the load by a combination of weights and spring balance or a load arm as described for large angle stepping motors and again monitor the angle with an encoder.

D-4 ONE STEP RESPONSE, NATURAL FREQUENCY AND SETTLING TIME

Couple a continuously rotating potentiometer to the motor output shaft and apply a voltage to the ends of the potentiometer track. Connect a detecting device such as an ultraviolet recorder from the potentiometer wiping contact to one side of the supply. When the motor is stepped to one step at a time, the resulting trace will show the one step response. Take care to ensure that the inertia of the potentiometer is small compared with that of the motor rotor and that friction is very small compared with the motor torque. For large motors, it may be possible to monitor shaft position with an optical encoder as in the torque displacement curve measurements.

The natural frequency is the inverse of the period of oscillation as observed on the curve of the one step response. The time taken for the rotor to remain within 1 percent (for otherwise agreed) of its final position should be taken as the settling lime. This is derived from the one step response curve.

D-5 MAXIMUM SLEW RATE

Apply a pulse train to the motor as described in D-6. Slowly increase the pulse rate from a low pulse rate (before the pull-in rate) to the rate just before the rotor loses synchronism. The resulting pulse rate is the maximum slew rate. Repeat this test for the opposite direction of rotation. Take care to avoid resonances.

D-6 PULL-IN RATE

The drive circuit should be such that the motor can be started by application of the pulse train which will cause the drive circuit to energize the next motor winding or windings in sequence. Additionally, the pulse train should be of the correct duration and not altered by 'switch on'. Apply a load to the shaft of the stepping motor such that the torque applied to the shaft is substantially constant with varying shaft speed. This may be achieved in several ways. For large motors, it is convenient to use a particle brake to supply the load, since the torque is approximately proportional to the supply current. Because of the high inertia it is not possible to use a particle brake for small motors (size 34 and smaller) and other devices such as a prony brake may be used. If a cast iron drum of low inertia is mounted on the motor shaft and hardwood blocks or pads brought to bear on the surface, then provided the surfaces are clean, a fairly low stiction which is comparable to running torque can be obtained (see Fig. 7).

The torque will depend upon the force between the pads and the drum and should be pre-calibrated. Because of the difficulty in setting the torque, it is more convenient to alter the drive frequency and the procedure is then as follows:

Set the prony brake to a low value of torque (10 percent of holding torque). Set the pulse rate to a low value (for example, 20 pps). Initiate the pulse train and see whether the motor pulls into speed without hesitation. Turn off the pulse train, increase its rates, initiate it again and observe the motor. Stop the pulse train. If the motor had pulled into synchronism again without hesitation repeat the procedure until it does not. When the motor fails to respond correctly reduce the pulse rate slightly and re-initiate. By increasing and reducing and again increasing the pulse rate, a fairly accurate figure of pull-in rate for the' applied torque can be determined. It is important to check the prony brake torque after this test. Then increase the torque to a higher value and repeat the test. Eventually plot a curve of pull-in rate versus torque. It is necessary to quote the moment of inertia of the load (drum) along with the curve. When using a particle brake, it may be preferable to change the brake current and, therefore, motor load instead of the pulse rate.

D-7 PULL-IN RATE WITH INERTIA

If it is required to quote the pull-in rate versus inertia or the pull-in rate with inertia versus load, proceed as in D-6; for the former, omit the load and add various known inertias to the shaft and, for the latter, add known inertias and load.

D-8 PULL-OUT TORQUE

As in D-6, the inertia of the test apparatus affects the results and so the particle brake and dynamometer methods should bc used only for the larger motors and cord/spring balance combination for the smaller motors (size 34 and smaller). A schematic diagram of a particle brake and torque transducer arrangement is shown in Fig. 8 and of a reaction dynamometer in Fig. 9. If the particle brake is removed and finger pressure applied to the torque transducer shaft, the inertia is lowered so that smaller motors may be tested depending upon the inertia of the torque transducer.

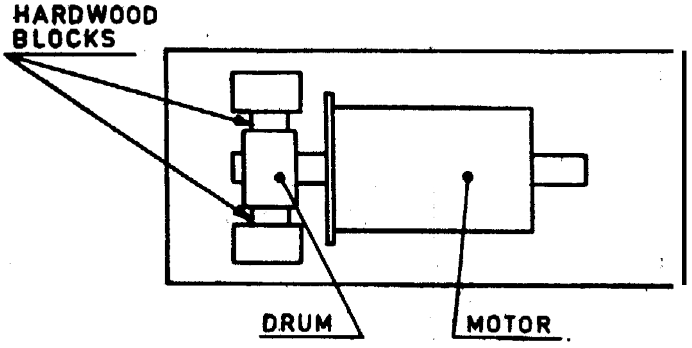


FIG. 7 METHOD OF APPLYING A TORQUE TO A SMALL MOTOR

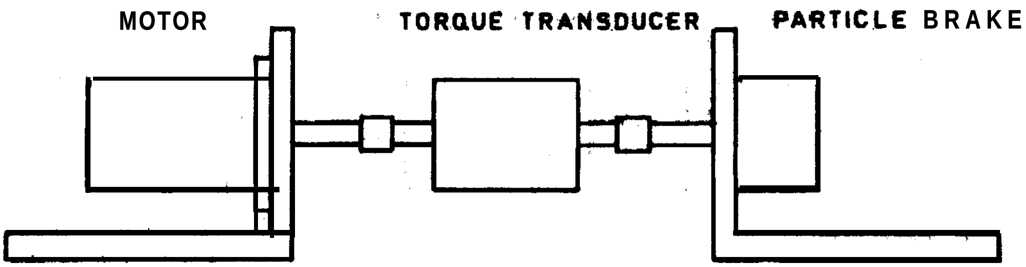


FIG. 8 TEST RIG POR PULL-OUT TORQUE MEASUREMENT USING TORQUE TRANSDUCER AND PARTICLE BRAKE

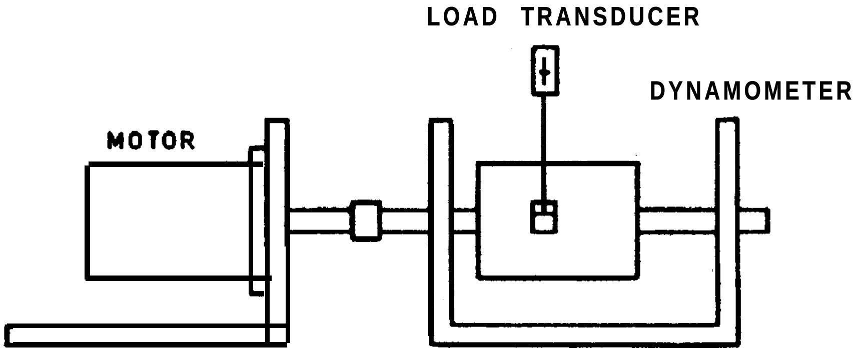


FIG. 9 TEST RIG FOR PULL-OUT TORQUE MEASUREMENT USING DYNAMOMETER

Set a low pulse train rate as in D-4 and start the motor. Increase the load until the motor falls out of synchronism. Make a note of the load applied just before synchronism is lost. With the load removed, restart the motor and increase the pulse rate. Then re-apply the load and increase this until the motor again loses synchronism and note the load again just before loss of synchronism. Repeat this for several values of pulse rate until-the, *motor will run no faster. It will be necessary to start at a lower frequency and ramp up for the higher speeds when the motor is running in its slew mode.

Two methods using cord and spring balance are shown in Fig. 10 and 11, the results for each being similar. The system (Fig. 10) using only one spring balance requires a cord loop and a pulley mounted on a raiseable arm. As the arm is raised, the cord tension is increased and the torque applied is also increased; the torque is then the product of motor pulley radius and the balance reading. The system shown in Fig. 11 requires the reading of both balance simultaneously; the torque is then the product of the difference in balance readings and

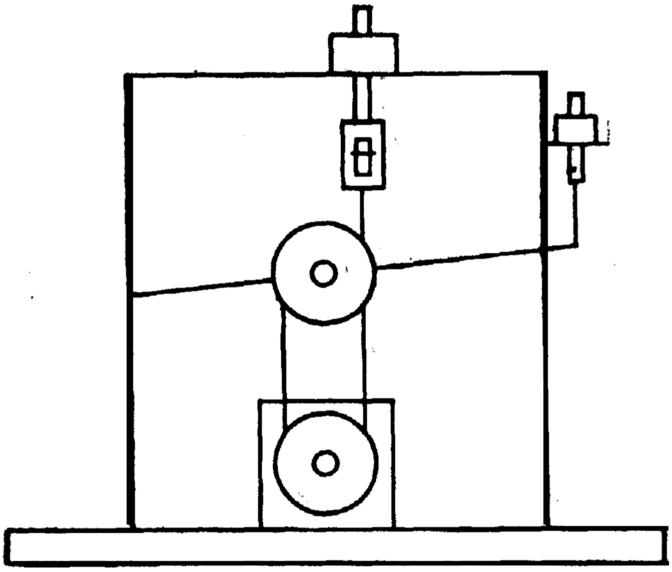


FIG. 10 METHOD OF PULL-OUT TORQUE MEASUREMENT USING CORD AND SPRING BALANCE

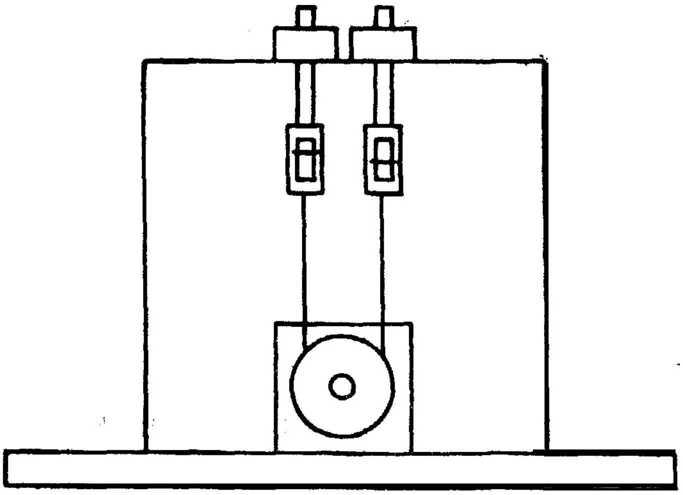


FIG. 11 METHOD OF PULL-OUT TORQUE MEASUREMENT USING CORD AND TWO SPRING BALANCES

the pulley radius. Include the diameter of the cord in the calculation only if it has not been possible to choose a cord sufficiently small to make this unnecessary.

In all cases the moment of inertia of the test load should be quoted.

D-9 MAXIMUM REVERSING RATE

Having determined the pull-in rate as in D-6, set the pulse rate with the motor unloaded, so that the motor is running with a pulse rate less than half the maximum pull-in rate. Reverse the motor normally by a change in logic level input to the drive circuit, taking care that the final pulse in one direction and the initial pulse in the other direction are not foreshortened,. Increase the pulse rate until the motor ceases to respond correctly (loses or gains steps). Then lower again until the motor functions correctly. This value of pulse rate is the maximum reversing rate.

It is often the case that motor hesitation (incorrect response) can be observed visually, but it is recommended that a more positive indication of lost steps should be made. If the rotor is driven a certain number of steps in each direction, any lost or gained steps will result in a variation of the final position of the shaft. This can be observed much more easily than motor hesitation. If a shaft position monitoring device (for example, as mentioned in D-4) is used, take care to ensure that the inertia is low enough not to affect the response unduly.

D-10 RESPONSE

Apply a pulse train to the motor as described in D-6 and raise the pulse rate slowly until the motor loses synchronism. Note the pulse rate, Starting from a slightly lower pulse rate (at which the motor runs satisfactorily) and, rapidly but smoothly transversing the previously noted pulse rate, again raise the pulse rate slowly until the rotor again loses synchronism. Repeat this procedure to locate all resonant rates until the motor will no longer run. Reverse the procedure (decreasing pulse rate) to find the upper thresholds of the resonant areas.

An alternative method of starting the stepping motor is to turn the shaft at a speed above the desired synchronous speed and to allow the rotor to fall into synchronism, continuing the test as before.

ANNEX E

(Clause 8.1)

DIMENSIONS

E-l Tables 3 and 4 give approximate installation dimensions of standard frame sizes in metric units (see 8).

E-2 The meanings of the letter symbols are illustrated in Fig. 12, 13 and 14.

R-3 In Table 3, where no values arc given for dimension 0, these are not standardized.

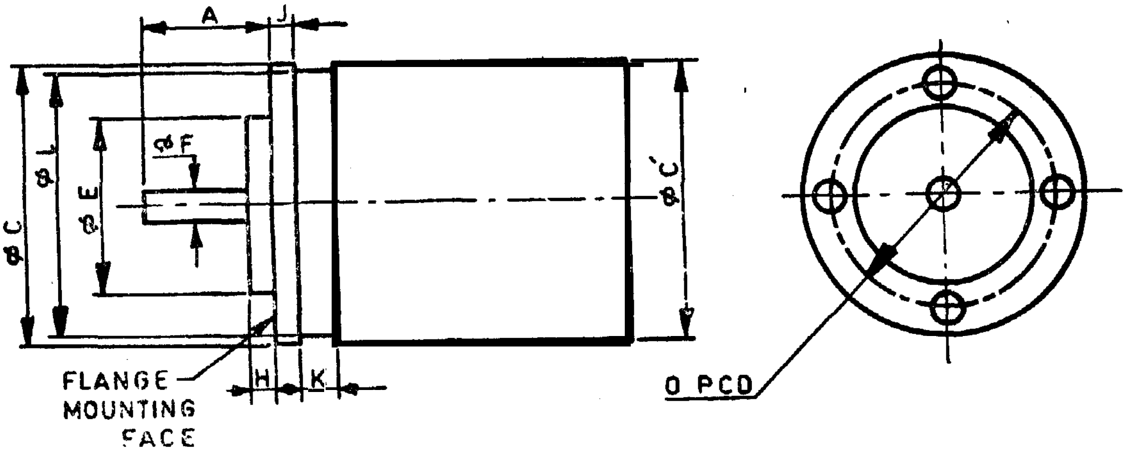


Fig. 12 Mounting Dimensions Applicable to Frame Sizes 05, 08, 20 and 42

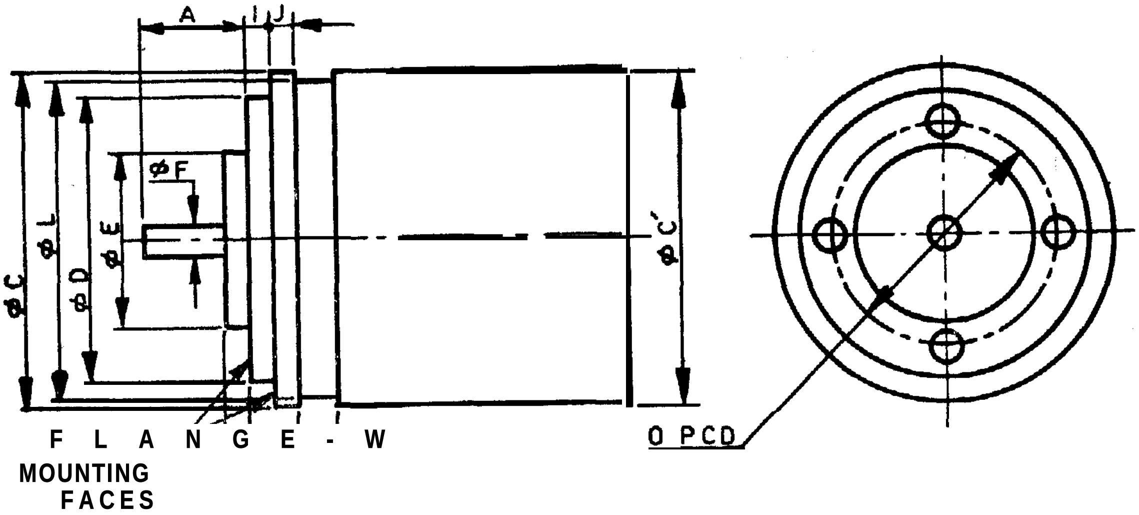


Fig. 13 Mounting Dimensions Applicable to Frame Sizes 11, 15, 18 and 23

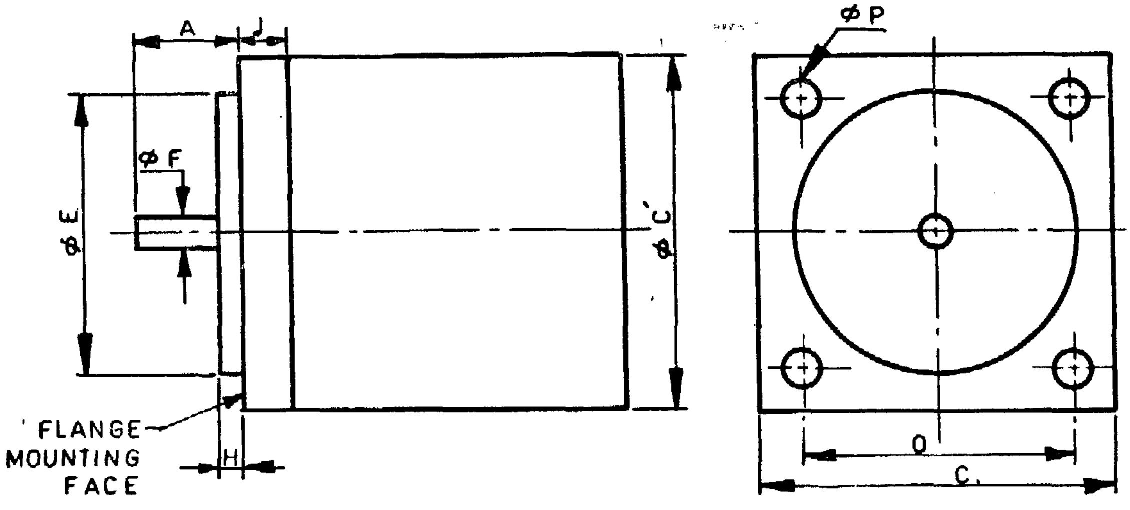


Fig. 14 Mounting Dimensions Applicable to Frame Sizes 23, 34 and 42

The fixing holes in Fig. 12 and Fig. 13 are tapped, but the threads are not standardized.

E-4 In Table 4, where there are no entries in the 'number of teeth' and 'diametral pitch' columns, a plain shaft is signified.

E-5 The run-out of the mounting spigots with the shaft extension. measured by the method given in IS 2223 : 1983 shall not exceed the following:

Frame sizes 05, 08, 11, 15, 18 and 20	0·03 mm full indicator measurement
Frame sizes 23, 34 and 42	0·08 mm full indicator measurement

The run-out of squareness of the flange mounting faces to the shaft extension, measured by the method given in IS 2223 : 1983, shall not exceed the following:

Frame size 05	0·03 mm full indicator measurement
Frame sizes 08, 11, 15, 18 and 20	0·05 mm full indicator measurement
Frame sizes 23, 34 and 42	0·08 mm full indicator measurement

The maximum shaft extension run-out, measured by the method given in IS 2223 : 1983, but at a distance of 6·5 mm from the bearing, shall not exceed 0·2 mm.

Standard Mark

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